

1- A 7.5 cm O.D refrigerant pipe is exposed to an environment in which the heat transfer coefficient is $15 \text{ W/m}^2\cdot\text{K}$. What thickness of cork insulation must be applied to reduce heat transfer to 20%, thermal conductivity of cork is $0.03 \text{ W/m}\cdot\text{K}$. If the heat transfer coefficient of air is $6 \text{ W/m}^2\cdot\text{K}$ and thermal conductivity of an insulation material used is $0.1 \text{ W/m}\cdot\text{K}$ will the insulation be effective on a 3 cm O.D pipe.

2- Drive an expression for the general equation of heat conduction in spherical coordinates.

① Data: OD = 7.5 cm

$$h_o = 15 \text{ W/m}^2\cdot\text{K}$$

$$Q_2 = 0.2 Q_1$$

$$K_{\text{cork}} = 0.03 \text{ W/m}\cdot\text{K}$$

$$h = 6 \text{ W/m}^2\cdot\text{K}$$

soln

without insulation

$$Q_1 = \frac{\Delta T}{\frac{1}{h_o \cdot 2\pi r_2 L}}$$

with insulation

$$Q_2 = \frac{\Delta T}{\frac{\ln r_3/r_2}{2\pi K_{\text{cor}} L} + \frac{1}{h_o \cdot 2\pi r_3 L}}$$

But $Q_2 = 0.2 Q_1$

$$\frac{\Delta T}{\frac{\ln r_3/r_2}{2\pi K_{\text{cor}} L} + \frac{1}{h_o \cdot 2\pi r_3 L}} = 0.2 \frac{\Delta T}{\frac{1}{h_o \cdot 2\pi r_2 L}}$$

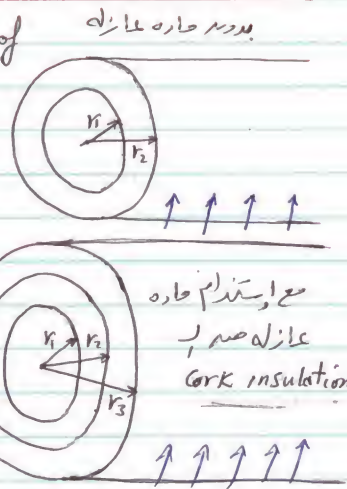
$$\frac{\ln r_3/0.0375}{2\pi \times 0.03} + \frac{1}{2\pi \times 15 \times r_3} = 1.41471$$

let $r_3 = 5 \text{ cm} \Rightarrow \text{LHS} = 1.7384$
 let $r_3 = 4.5 \text{ cm} \Rightarrow \text{LHS} = 1.203$ } by interpolation

$$\frac{r_3 - 5}{4.5 - 5} = \frac{1.4147 - 1.7384}{1.203 - 1.7384} \Rightarrow r_3 = 4.6977 \text{ cm}$$

$$S_{\text{ins}} = 0.9477 \text{ cm} \approx 1 \text{ cm}$$

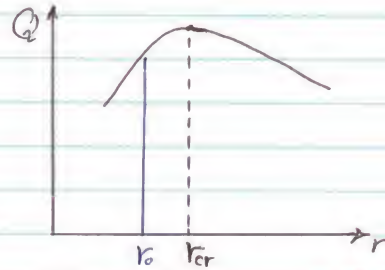
Req: Thickness of insulation



②

$$r_0 = 1.5 \text{ cm}$$

② لائىه سوڭ بۇدى الى نىزاوه



2- Drive an expression for the critical radius of insulation for cylindrical layer.

Req:- (a) α (b) γ_f (c) ϵ_f

A 3D perspective diagram of a rectangular block. The length of the block is labeled L with a double-headed arrow. The width of the block is labeled b with a double-headed arrow. The height of the block is labeled h with a double-headed arrow. The block is drawn with dashed lines to show its three-dimensional structure.

$$\therefore m = \sqrt{\frac{hP}{K A_c}} \quad \text{and} \quad p = 2(b+l)^{mk} \quad \text{and} \quad A_c = b \times l$$

$$\theta_0 = T_0 - T_\infty$$

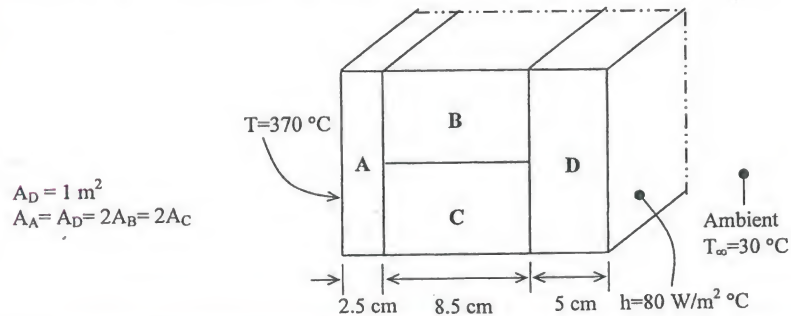
$$Q_{\text{without}} = h (b \cdot l) \theta_0$$

$$Q_{max} = h (bl + 2bL + 2Ll) \theta_0$$

$$\eta_{fin} = \frac{Q_{fin}}{Q_{max}} \quad \text{and} \quad \epsilon_{fin} = \frac{Q_{fin}}{Q_{without}}$$

Question No. 1:

- a) Define the following: thermal conductivity of a material, thermal contact resistance, and critical radius of insulation of a cylinder.
- b) A composite wall is constructed as schematically shown in the figure. The thermal conductivities of the used materials are: $k_A = 150 \text{ W/m}^\circ\text{C}$, $k_B = 30 \text{ W/m}^\circ\text{C}$, $k_C = 70 \text{ W/m}^\circ\text{C}$, and $k_D = 50 \text{ W/m}^\circ\text{C}$. The thermal contact coefficient " h_c " in the interface between the parts A and B is $800 \text{ W/m}^2 \text{ }^\circ\text{C}$ and between the parts C and D is $1000 \text{ W/m}^2 \text{ }^\circ\text{C}$. On the other hand perfect contact is considered between parts A and C and also between B and D. If the heat flow through the wall is assumed to be one-dimensional, determine the rate of heat transfer per unit area of the wall. Also, determine the outer temperature of the wall.



Given:- Composite plane wall

$$R_A = \frac{L_A}{k_A \cdot A_A} = \frac{0.025}{150 \times 1} = 0.000167$$

$$R_B = \frac{L_B}{k_B \cdot A_B} = \frac{0.085}{30 \times 0.5} = 0.00567$$

$$R_C = \frac{L_C}{k_C \cdot A_C} = \frac{0.05}{70 \times 0.5} = 0.0024286 \quad \& \quad R_{thc(A/B)} = \frac{1}{h_c \cdot A_B} = \frac{1}{800 \times 0.5} = 0.0025$$

$$R_D = \frac{L_D}{k_D \cdot A_D} = \frac{0.05}{50 \times 1} = 0.001 \quad \& \quad R_{thc(C/D)} = \frac{1}{h_c \cdot A_C} = \frac{1}{1000 \times 0.5} = 0.002$$

$$\Sigma R_{th} = R_A + R_{eqn} + R_D$$

$$R_{eqn} = \frac{0.008167 \times 0.00443}{0.008167 + 0.00443} = 0.0028725$$

$$\Sigma R_{th} = 0.00404$$

$$R_{conv} = \frac{1}{h \cdot A_D} = \frac{1}{80 \times 1} = 0.0125$$

$$Q = \frac{\Delta T}{\Sigma R_{th} + R_{conv}} = \frac{370 - 30}{0.01654} = 20556.85 \text{ Watt}$$